Composition, Physical State and Distribution of Ices at the Surface of Triton

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Primary Reference: Quirico, E. et al., 1999 *Icarus* 139, 159-178.
Secondaries: Cruikshank, D.P., et al., 1993 *Science* 261, 742-745.
de Pater, I. and Lissauer, J. *Planetary Sciences.*

Although significant progress has been made in the last two decades since the *Voyager* missions, our knowledge of the planets and satellites of the outer solar system still has many gaps. One of the least understood bodies is Triton, the largest satellite of Neptune. An active debate is currently underway on whether Triton formed with Neptune (as it would seem from its close orbit and spherical shape) or was captured (which would explain its retrograde motion), so Triton's origin remains a mystery. Equally puzzling is the physical appearance of this small, icy moon. *Voyager 2* passed by the Neptune system in August of 1989, finding Triton to be a world of varied, relatively young terrain by solar system standards. At a surface temperature of $\sim 38 \pm 4$ K, Triton is the coldest body in the solar system, composed mostly of solid N_2 ice and trace organic compounds. The level of cratering suggests that moon's surface is relatively young, estimated at an age of a few billion years. Evidence exists for viscous, icy eruptions in the past, possibly from cryovolcanoes, which likely eroded away much of the early cratering. Active geysers have also been observed on this moon, sending plumes of liquid nitrogen up to ~ 8 km into its tenuous nitrogen atmosphere.

In the fifteen years since *Voyager 2* first studied Triton, astronomers have had to rely on ground-based observations to tell us more about this enigmatic world. In particular, with the advances currently being made in spectroscopic resolution, infrared spectra have been able to provide us with more detailed information about the surface features and atmospheric properties of Triton. Quirico et al. (1999) have used the 2.65 nm resolution of the United Kingdom Infrared Telescope (UKIRT) atop Mauna Kea to examine in detail the spectrum of Triton. By comparing their specta to improved laboratory data on the properties of several ices which are thought to be prevalent on the surface of Triton, and by utilizing a sophisticated numerical reflectance model, the authors have greatly elucidated the nature of the ice structure on this satellite. Their work hypothesizes either a two- or three-region terrain on Triton: in the first case, this terrain is described by a solid solution of N_2: CH_4: CO in which N_2 is the dominant molecule, along with an $H_2O + CO_2$ mix of pure water ice and carbon dioxide grains. The second terrain possibility has three regions: the N_2: CH_4: CO mix and two geographically separated H_2O and CO_2 terrains. The authors then use their reflectance model to place constraints on grain size and geographical abundance for each of the region constituents, determining that the surface of Triton is not granular, but rather composed of a compact crystalline solid. The best-fit model for the spectrum of Triton yields a surface temperature estimate of $35.6 \leq T \leq 41$ K. No more than 10% of the surface of Triton can be composed of pure CH_4 ice under these model constraints. Lastly, three new and unidentified bands have been detected in the spectrum at $1.749, 1.683$, and $1.543\,\mu$m. The identity, physical state and origin of these lines has yet to be determined, prompting the need for more comprehensive numerical modeling techniques for Triton's spectrum in the IR band, and perhaps a new understanding of the physical state of certain ices in the extreme cold of the outer solar system. Such an understanding and improvement in modeling and observing techniques would also prove useful in studying the Pluto-Charon system, which bears a strong resemblance to Triton in temperature, size and composition.